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THE GERMAN COPPER POSITION

~~Report No. 30~~

R&A 618

March 27, 1942

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SUMMARY

Germany's copper consumption requirements for 1942 are estimated at 275,000 tons. Consumption requirements for all of Axis Europe are estimated at 325,000 tons.

To meet this demand Axis Europe has a current supply of copper of approximately 260,000 tons. Output of virgin copper available to the Axis totals about 160,000 tons; scrap recovery is estimated at 100,000 tons.

Axis Europe's current copper supply thus falls approximately 65,000 tons short of equalling present consumption requirements. However, Germany entered 1942 with a stockpile of perhaps 115,000 tons of copper, which may be drawn upon to meet this deficiency.

It is believed, therefore, that Germany will have enough copper for all her essential requirements for 1942 and at least the first half of 1943.

I. INTRODUCTION

Although output of virgin copper in Europe is not large and Germany is denied access to the sources which formerly supplied no less than three-fourths of her needs, as a result of her foresight and resourcefulness Germany is finding it possible to meet her wartime requirements for copper. In essence, Germany is solving her problem (1) by restricting the use of copper and utilizing it for essential civilian and military needs only when no other material can be satisfactorily substituted; (2) by using every possible device to maximize her copper supply; and (3) by drawing upon a large stockpile of copper accumulated before the war to supplement her sources of current supply and meet her indispensable requirements.

Because of the existence of this stockpile, and Germany's success in cutting her consumption requirements and exploiting her available sources of current supply to the point where a balance is almost reached, the evidence suggests that Germany will have enough copper for both essential civilian and military needs for the balance of 1942 and at least the first half of 1943. Her position will become straitened before then only if she is forced to use up copper more rapidly because of an intensification of the war or experiences military reverses which involve the losses of current copper supply and make it impossible for her to recover scrap from the battlefield. If through political and military meas-

ures, Germany gets access to additional supplies of copper, she may not be embarrassed for want of the metal for a long time to come. Even the exhaustion of her reserves, furthermore, will not immediately jeopardize her ability to wage war, for unless she loses copper-producing areas now under her control she will still have enough copper for strictly military requirements.

The contribution of foresight--of planning for just such a war as she is now waging-- to the achievement of this relatively secure position must be emphasized. Not only had Germany accumulated a huge stockpile of copper to tide her over just such a situation as she now faces; as will be seen, well before the war she had cut non-military consumption of copper to the bone and had learned how to produce the material she needed for waging war with a minimum utilization of copper. When war came, she did not have to resort to hasty and ill-devised expedients. The detailed account of Germany's management of her copper situation provides an instructive example of the value of planning and resourcefulness in overcoming what appear to be crippling economic weaknesses.

II. GERMAN COPPER CONSUMPTION

A. Restriction on the Use of Copper

The steps which were undertaken first and which have contributed most to the easing of Germany's copper position were directed toward limiting consumption rather than toward increasing supply. The first restrictions antedated the beginning of Germany's rearmament program. With the initiation and expansion of that program, restrictions were extended until they embraced all but a very few essential non-military items for which no satisfactory substitute for copper could be found; ultimately, efforts were made to limit the use of copper in war materiel as well.

The first restrictions on the availability of copper in Germany preceded the armament program: they were an outgrowth of the need to husband Germany's slight and rapidly-dwindling supply of foreign exchange. The financial crisis of 1931 sharply restricted Germany's capacity to purchase goods from abroad, and quota restrictions were placed on all allocations of exchange for imports.

As early as 1934 a Nazi Germany already committed to a vast rearmament program began to ration copper for the express purpose of securing as much of the metal as possible for developing a formidable military machine. A quota system was adopted under which all users of copper were restricted to a limited percentage of their previous consumption. Only Government orders --

which were, of course, chiefly for military purposes -- and export goods were exempted. The obvious effect of the system was to release the largest possible proportion of the available supply of copper for the needs of the state, the chief of which, of course, was the re-establishment of Germany's dominant military position.

In May 1935 the use of copper was cut to 40% of the 1934 consumption rate, and the use of copper alloys from 40% to 75% of the 1934 rate.1/ In July the quotas were further reduced to 30% for copper and 20% and 50% for alloys. These quotas were even more severe than might be apparent at first glance, for they were supplemented by prohibitions on certain uses of copper. As early as August 1934 Germany stopped making copper available for roofing, architectural parts, and various luxury uses. Between December 1934 and April 1935 its use was banned for a long and constantly growing list of consumers goods, including hardware, kitchen utensils, and electrical appliances, and for a number of automobile parts and accessories. By the fall of 1935 the ban on copper had been extended to many capital goods. (For a more complete summary of the development of Germany's system for controlling the use of copper, see Appendix A.) To understand the rigor with which Germany was restricting the non-military use of copper it should be kept in mind, too, that the limitations and prohibitions which have been mentioned were imposed in the face of a rapid expansion

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1/ For the sources of the statements regarding Germany's restrictions on the use of copper, see the note at the end of Appendix A.

in industrial production. Between 1934 and the first half of 1939 industrial production in Germany increased almost 60%. Yet German manufacturers of non-military goods were limited to 30% of the copper they had used in the years of relatively low production, and for an extensive list of items they could not use copper at all.

In order to give the quota system needed flexibility, manufacturers were enabled to secure supplementary allotments of copper and its alloys when they could establish their need for the additional supplies. But it is extremely unlikely that supplementary allotments were permitted to make inroads into the amounts of copper earmarked for military consumption; they were probably used to adjust conflicting claims as among the various non-military uses of copper.

Even when it is as flexible as Germany's system obviously was, any system which controls the distribution of a commodity on the basis of its use in some previous period has obvious limitations, and these become more pronounced the farther one proceeds from the base period. The system of quotas for copper, based on a simple percentage of base-period consumption, tended to evolve into an allocation system, based on the relative urgency of alternative uses for the metal, and in March 1939 it was largely superseded by such a system. In effect, the Reich took responsibility for deciding in detail the uses to which copper could be put, in view of its own objectives, the relative urgency of competing needs for copper, the possibility of substituting

other materials for it, and similar considerations. The available supply was then alloted in such a way as to insure its being used for the state's most indispensable needs. Well before the advent of war, it is clear, the maximum diversion of copper from civilian to military use had been substantially achieved.

B. Substitution for Copper

The success of such a vigorous copper control program as Germany undertook depended in large part upon her ability to find satisfactory substitutes for the metal. Such substitutes were developed for a long and growing list of uses previously requiring copper. (See Appendix B). The substitute materials chiefly used were aluminum, steel alloys and copper-plated steel, zinc, porcelain, and plastics. Aluminum was used, among other things, for both bare and insulated wire, cables, bus bars, switch parts, wiring harnesses, coils, conduits, bearings, worm gears, and fixtures; magnesium was used for certain electrical parts; steel with various alloys and plating for tubes, armatures, turbine blades, and locomotive fire-boxes; zinc for fittings and castings; porcelain for tubes; and plastics for fixtures and bearings. According to German claims (see Appendix B) the substitute materials proved not only adequate but in many instances superior to copper, and American engineers confirm the technical possibility of substituting other materials for practically all industrial uses of copper

save motor windings and certain other electrical uses.[2] Of course, such substitution is not invariably economical; and frequently it necessitates the redesigning of equipment and involves a temporary loss of efficiency. But Germany was governed by the desire to gird for war, not by ordinary considerations of economy, and she had ample opportunity in the pre-war years to redesign equipment and adapt her industrial system to a lessened dependence on copper.

Some indirect evidence of the amount of copper saved through substitution is furnished by what is known about the consumption of the principal substitute material, aluminum. The American Consul in Frankfort-on-the-Main, who for many years followed German industrial developments closely, reported that in 1936 from 25,000 to 30,000 tons[3] of aluminum were used for purposes formerly served chiefly by copper.[4] Since the ratio of substitution is roughly 1 ton of aluminum for 1½ to 2 tons of copper, this estimate would suggest that 35,000 to 50,000 tons of copper -- nearly 1/6 of Germany's average consumption for 1934 to 1936 -- was annually released for military use as a result of the substi-

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2/ Engineers interviewed include the following: Messrs MacClinchie, Mark Arndt (formerly with Westinghouse), MacKay, and Thomas of the Rural Electrification Authority; Mr. H. H. Thompson of the Washington office of Westinghouse; Mr. Norman of the Power Section of War Production Board; Mr. Gleason, formerly Director of Research and Development with Guggenheim Co. now with Office of Price Administration; Mr. James Kemp of the Conservation Unit of War Production Board; and Mr. Theodore Berrier of the American Telephone and Telegraph Co.

3/ Statistics are quoted in metric tons throughout. A metric ton = 2204 lbs.

4/ German Metal and Mineral Notes, Aug. 1, 1936. No. 141.

tution of aluminum alone. By 1939 the saving had probably reached a still higher level.

In America, where so much more concern is felt about the supply of aluminum than about the supply of copper, a question which naturally suggests itself is whether Germany's supply of aluminum was ample to satisfy both the demand diverted from copper and the enormous requirements of the aircraft industry. Between 1932 and 1938 Germany's aluminum consumption increased tenfold, from 18,000 tons to 182,000 tons. But, despite the fact that Germany was largely dependent upon imported bauxite, production of aluminum, which was deliberately encouraged as a war measure, increased almost as rapidly as consumption, and her aluminum position in the pre-war period showed no evidence of appreciable strain. No significant restrictions were imposed upon the consumption of aluminum until September 1939, and those restrictions exempted many of the uses where aluminum had replaced copper.5/ Now with the whole continent under Germany's domination, her aluminum position is even more secure. The British estimated that the 1941 aluminum supply of Axis-Europe totalled 430,000 tons (including 70,000 tons in unoccupied France) against consumption requirements of about 400,000 tons. For 1942 supply is estimated at about 490,000 tons against consumption of about 450,000 tons.6/

5/ Institut für Konjunkturforschung, Neun Monate Deutsche Kriegswirtschaft, 14 Jahrgang 1939/40, June 15, 1940, pp. 154 ff; Industrieblatt, No. 1, Jan. 6, 1940, pp. 22-23. "Increased Tension in German Light-Metal Supply," Report of S. B. Redecker, American Consul, Frankfort, November 1, 1939.

6/ BMEW, SEED, No. 119, Dec. 29, 1931, par. 60 and 61.

C. Military Consumption

The very thoroughness with which Germany had diverted copper from civilian to military uses before the war began suggests that little more could be done in this direction after the outbreak of war. In any case, rigorous as were Germany's restrictions on the civilian consumption of copper, they alone would not account for Germany's ability to find enough copper for her needs while engaged in a war of unprecedented magnitude and denied access to the sources which formerly supplied her with three-fourths of her new metal requirements. Supply considerations and the most accurate estimates which can be made of consumption requirements in various categories (see page) both suggest that German consumption of copper is proceeding at about the pre-war rate of 275,000 tons per year and that consumption for all Axis-Europe is in the neighborhood of 325,000 tons. In the United States the 1942 consumption of copper for military purposes alone is estimated at 1 1/3 million tons. The facts clearly suggest that Germany has managed to effect drastic economies in the military, as well as in the civilian, utilization of copper.

This hypothesis is supported by all the information available from the Military Intelligence Division and the British Ministry of Economic Warfare on the copper content of German munitions and military equipment.[7/] Very significant savings are made in connection with cartridge cases, which in the United

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7/ MID, Summary of Technical Reports Regarding Weapons, War Industry and Transportation, No. 6, 1940. BMEW, Weekly Armaments Report, No. 43, Dec. 13, 1941, and No. 47, Jan. 17, 1942.

States accounts for perhaps half of all current consumption of copper. The standard practice in the United States has been to make cartridge cases of copper or brass without steel. German small arm cartridges dated as early as 1938 have a casing of steel covered with a thick layer of copper, and M.I.D. believes that the utilization of steel as well as copper in cartridges has been standard practice in Germany since at least that year. Recently examined cartridges have deep-drawing steel cases and a copper coating of only 5%.

Large savings of copper are also effected in the manufacture of rotating or driving bands, which represent the only important use of copper in medium and large sized shells. The driving bands on 105 mm. German shells have a bimetallic content, the 3mm. inner strip being made of soft iron and the 2.2 mm. outer strip of copper. The resulting saving of copper is about 60%. In shells of 120 mm. and larger, driving bands made of sintered iron powder are finding increasing use. Apparently naval shells are the only important types where 100% copper bands continue to prevail.

The full significance of these savings in the manufacture of ammunition may be appreciated from the fact that 72% of all the copper consumed in the United States in 1942, considering essential civilian as well as military uses, will be used for ammunition.[8/] We shall pour 1,200,000 tons of copper into ammuni-

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8/ Figures obtained from Division of Research and Statistics, War Production Board.

tion; the British estimate that the Germans will use only 140,000 tons. While our output of ammunition will probably exceed Germany's in 1942, it will certainly not exceed it by a ratio of 9 to 1. It is abundantly clear that the German consumption of copper per unit of ammunition is much lower than America's, and that the quantitative saving of copper from the economies they have developed are tremendous.

Less is known about other items of German military equipment, but the existing evidence suggests that in their manufacture, too, important economies of copper have been effected. It is reasonable to suppose that less copper is used in their motorized military equipment than in ours, if only because German automobiles and trucks have long been built with less copper than is employed in comparable American machines. In German aircraft as well considerable reduction in the use of copper has been effected by the substitution of other materials. British inspection of a captured German submarine, built in 1941, also reveals a marked substitution of steel, aluminum, and plastics for copper.

Comparison of copper consumption in Great Britain and Germany between 1932-33 and 1938 furnishes dramatic evidence of Germany's success in restricting civilian consumption of the metal. While total industrial output almost doubled in Germany between 1932-33 and 1938, utilization of copper increased only 30%. In contrast, in Great Britain, where no effort was made to restrict the use of copper, a 34% rise in industrial production was accompanied by a 71% increase in the consumption of copper.

Table I (see Appendix C) shows the situation at a glance and gives the data for a number of specific industries which use relatively large quantities of copper or its substitutes.

D. Germany's Present Consumption Requirements

On the basis of all the available evidence about supply and the production and construction of both civilian goods and war materiel, the British estimate that total copper consumption requirements for 1942 for all of Axis-Europe total 325,000 tons.9/ Germany alone is expected to consume 275,000 tons, roughly the amount it is estimated she was consuming in the years immediately before the war. Italy, it is believed, will require 30,000 tons, and the rest of occupied Europe 20,000 tons.

The estimate of continental copper requirements is broken down into particular uses as follows:

Item:	Tons
Aircraft	15,000
Land and sea transport	25,000
Other military (munitions	140,000
Electrical uses	85,000
Foil and powder	25,000
Machinery	15,000
Building	5,000
Chemicals, brewing, and food	5,000
Unclassified	10,000
Total	325,000

9/ Axis Aluminum Situation, Report of British Air Ministry, transmitted via American Embassy in London by General J. T. McNarney to U. S. Army General Staff (see files of MID, Central European Section). The total consumption requirements estimated in this report are identical with the estimate of the British Ministry of Economic Warfare. SEED, No. 119, Dec. 29, 1941, par. 54

Three hundred and twenty-five thousand tons of copper is a small amount in comparison with current American consumption of 1,700,000 tons. It suggests an amazingly economical utilization of copper in civilian goods, and above all, in war materiel, which is being produced in great volume. But 325,000 tons of copper is a large amount for a continent which, as will be seen, produces less than half that amount of virgin metal and which has long been dependent upon sources of supply to which she no longer has access. How has Germany managed to find the copper for her irreducible needs?

III. GERMAN COPPER SUPPLY

A. Output of Virgin Copper

The same determination, resourcefulness, and foresight apparent in Germany's effort to control her consumption of copper are manifest in her endeavors to insure and increase her copper supply. Germany is exploiting the copper resources of Europe with the utmost vigor and ruthlessness in order to expand output of virgin metal. She is looting occupied Europe and Germany itself and systematically scouring the battlefields of the continent to find copper scrap. Because of her thoroughgoing preparation for the war she is now waging, furthermore, she is not entirely dependent upon these twin sources of current copper supply. Long before the war, in anticipation of just such a situation as she faces today, Germany began to accumulate a stockpile of copper to tide her over the period in which current supply would be insufficient for her needs.

Current annual output of virgin copper available to the Axis totals about 160,000 tons[10], distributed approximately as follows: Germany 40,000, Yugoslavia 65,000, Norway 20,000, Finland 12,000, Sweden 10,000, and others 13,000. Were Germany able to restore production in the British-owned Spanish mines[11] from its

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10/ This is approximately the British estimate.

11/ Early in 1941 MID reported that Spanish output was only 100 tons per month. (Radiogram received at War Dept. March 31, 1941.)

present negligible figure to the 1938 level of 30,000 tons and through conquest or intimidation acquire Turkey's[12] complete output of about 10,000 tons, she could increase her annual supply to nearly 200,000 tons. These increases, however, are highly conjectural, and it is not to be overlooked that there is also a chance that Germany will lose sources of copper now available to her, notably in Scandinavia.

B. Recovery of Scrap

Germany's success in expanding the recovery of copper scrap is in many respects a more remarkable achievement than her success in expanding the production of virgin metal. In pre-war years the recovery of scrap in Europe evidently amounted to about 75,000 tons, 40,000 tons in Germany[13], 35,000 tons in the rest of the continent.[14] A large proportion of this was new scrap obtain-

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12/ It is not known to what extent deliveries are being made under the trade agreement of October 1941, which promised Germany the whole copper output of Turkey. (BMEW, SEED, No. 111, Oct. 29, 1941, par. 86 and 87.)

13/ MID reports annual figures for 1934-38 obtained from the American Consul at Frankfort, Germany. Report on Copper, No. 4120, March 20, 1940. These figures, adjusted for net imports of scrap, check closely with those on total scrap consumption provided the writer by Mr. Batty of the British Embassy from a report on German copper made in Jan. 1940, for the British Ministry of Economic Warfare.

14/ Figures on scrap for many countries are fragmentary, but the most reliable are those given by Metallgesellschaft, Metal Statistics, 1929-1938, pp. 11 and 13. Germany accounts for a somewhat higher share of European scrap recoveries than its share in total consumption. This seems quite reasonable. Unfortunately no breakdown between recovery of old scrap (from metal previously in use) and new scrap (from clippings, punchings, etc., resulting from manufacturing processes) is available. In the United States in recent years about 40 percent of scrap recoveries have been new and 60 percent old.

ed from fabrication processes as opposed to old scrap salvages from articles formerly in use. Since total continental production of copper products is substantially lower than in pre-war years, less new scrap is available to Germany than before the war. Nevertheless, it is believed that Germany has increased total recovery of scrap from 75,000 to 100,000 tons.[15] She has accomplished this by picking Europe's vast battlegrounds clean of cartridges and scrap and by ruthlessly looting the continent -- not excepting Germany itself--of its old copper. Early in the war Germans were asked "voluntarily" to give up copper utensils and similar objects,[16] and household utensils and personal effects are being summarily seized in occupied countries.[17] In Germany and Denmark copper coins are being withdrawn from circulation.[18] French monuments are apparently reaching the melting pot.[19] German sea raiders are reported to be stripping captured vessels of copper and brass fittings.[20] Since at least March 1940 Germany has been seizing

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15/ BMEW, SEED, No. 119, Dec. 29, 1941, par. 54. The MID contention (op. cit.) that after the first year of the war scrap recoveries in Germany will fall from the pre-war average to about 20,000 tons per year does not seem tenable, despite the likelihood that the "capital fund," so depleted during the World War, was not restored by 1939.

16/ Institut für Konjunkturforschung, Neun Monate Deutsche Kriegswirtschaft, June 15, 1940, pp. 154 ff.

17/ See report of Military Attache in Berlin. M/A Berlin, No. 18738, Nov. 3, 1941; also Intercept 10439, Oct. 30, 1941.

18/ New York Times, February 17, 1942

19/ German press report, M/A Berlin, No. 18770, Nov. 17, 1941.

20/ The Metal Bulletin (London), July 29, 1941, p. 4.

church bells in Germany and, presumably, occupied countries as well.[21] In late 1941 it was reported that in some cases copper roofs had been removed from buildings in Vienna.[22] While such measures as these bespeak the determination of Germany, they do not necessarily indicate that she is at the end of her rope so far as locating sources of old scrap is concerned. Since copper has been used in Europe for centuries there still remain many copper articles which can be drawn into the scrap supply, and every new military engagement spells more scrap for the power in position to exploit the battleground. If her military victories continue, Germany should be able to maintain and possibly increase, her present high scrap recovery rate for some time to come.

C. Germany's Stockpile of Copper

In addition to her sources of current supply Germany has an ace in the hole: a formidable stockpile of copper accumulated to forestall the critical shortage of copper she experienced during the first World War. The exact size of this stockpile is unknown, but the German press was premitted to publish a figure of 200,000 tons on the eve of the war.[23] The British Ministry of Economic Warfare estimates that the stockpile aggre-

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21/ Institut für Konjunkturforschung, op. cit. This decree of March 15, 1940, required delivery of church bells and registration of copper roofs for later delivery.

22/ Report of Military Attache, Berlin

23/ See Deutsche Allgemeine Zeitung, Aug. 17, 1939.

gated no less than 300,000 tons.[24] This estimate is based on three assumptions: (1) that German wartime consumption would be about 300,000 tons annually, or roughly equivalent to average German consumption from 1934 to 1936, a period when rearmament was heavy but stockpile accumulation probably slight; (2) that the Germans expected to cover about half this amount from domestic production and imports from continental Europe; and (3) that the Germans anticipated a war of about two years' duration which would, on the basis of the above assumptions, exhaust the stockpile.[25] It is certain that during 1937 and 1938 Germany imported at least 200,000 tons of copper more than she needed for current consumption, even when ample allowance is made for the high rate of industrial production during those years. The excess imports went to war reserves, to which further additions were probably made in the first half of 1939. Whether or not the British are correct in these conjectures about German copper calculations, it is reasonable to believe that Germany entered the war with a copper stockpile of approximately 300,000 tons. In addition, it should be remembered, she had large stocks of fabricated products containing copper - notably munitions.

24/ BMEW, SEED, No. 95, July 7, 1941, par. 142-148; ibid, No. 119, Dec. 29, 1941, par. 54.

25/ This summary statement of the method used by the British has been pieced together from conversation with Mr. Batty of the British Embassy in Washington, and the incomplete explanation contained in a report on German copper made in January 1940 by Mr. O. W. Roskill to the British Ministry of Economic Warfare.

IV. GERMANY'S PRESENT COPPER POSITION

Most of the figures which have been given for both German copper consumption and supply represent simply the best estimates which can be made. Any assessment of Germany's present copper position, resting as it must upon these estimates, is necessarily conjectural. Nevertheless, within broad limits, it is possible to reach certain conclusions of value about Germany's present situation.

As has been said, Germany started the war with a reserve of no less than 300,000 tons of copper. In the first phase of the war, from September 1939 to the end of the French campaign in June 1940, there is reason to believe that she was able to keep this reserve intact. The amount of copper she seized as loot in France, Belgium and the Netherlands[26] -- by her own admission 65,000 tons of copper and 17,000 tons of brass -- more than compensated for the difference between consumption and supply during the period.

In the latter half of 1940, a period of high consumption and low supply, the British believe that the Germans were forced to make inroads in their reserves to the extent of 27,000 tons a month. Even when allowance is made for the disorganized state of

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26/ From MID which obtained these figures from the German Military Attache in Washington, Dec. 17, 1940. The Germans are reported to have seized between 25,000 and 30,000 tons of copper at French ports alone. (See The Metal Industry, London, April 18, 1941, vol. 58, p. 357.) Allowance for understatement and inclusion of loot obtained in Poland in 1939 would suggest a higher figure than that given by the Germans.

occupied Europe at this time and the return of numerous German soldiers to the factories to produce munitions for the next campaign, this figure appears somewhat too high. It seems more reasonable to assume that reserves were depleted at the rate of approximately 17,000 tons a month.

If this more conservative estimate is accepted, it appears that Germany started 1941 with a stockpile of approximately 200,000 tons. In the course of the year she was unquestionably forced to make further inroads into it. Consumption was in the neighborhood of 325,000 tons; output, even assuming a heavy recovery of scrap, could hardly have totalled more than 240,000 tons. To find the additional metal she required, Germany was again forced to dig into her reserves to the extent of perhaps 85,000 tons.

Nevertheless, she began the current year with a stockpile of perhaps 115,000 tons. If, as has been estimated, she again consumes 325,000 tons and produces 260,000 tons she will end the year with 50,000 tons of copper still at her disposal. If she succeeds in getting her hands on more Spanish and Turkish copper, even smaller withdrawals from surplus will suffice; she may go into 1943 with a stockpile of over 70,000 tons. In either case, unless the war assumes a more violent character or the tide of fortune begins to run strongly against Germany so that she loses some of her sources of current supply and will have less opportunity to exploit the scrap resources of the battlefield, there is no reason to believe that she will exhaust

her reserves of copper in the near future.

It must be remembered, furthermore, that the exhaustion of the stockpile would not immediately impair Germany's military strength, because her sources of current copper supply come close to being sufficient for her complete military requirements; they are inadequate only for total military and civilian needs. Only in the event of a long war, or a war of greater intensity, where copper is used in larger quantities and less opportunity is given Germany to exploit her sources of current supply, are shortages likely to develop which will contribute to Germany's downfall. If the war is prolonged and increasingly violent, however, then, particularly if the tide of battle turns against Germany, her copper position can easily deteriorate and contribute to her military defeat.

APPENDIX A. PROHIBITIONS AND RESTRICTIONS ON THE USE OF COPPER IN GERMANY.

Date	Use	Exemptions
Mar. 1934	Boards set up to control purchase and consumption of all industrial raw materials and semi-manufactures	
Apr. 1934	Copper rationing introduced; quotas based on early 1934 consumption	Goods for export and Government orders. Also apparently exempt in all subsequent orders until outbreak of war. Exports, however, under complete control of Government
June 1934	Copper prohibited for bare electric wire or cable. (High tension)	Power line for electric railroad; low and medium-tension wire; insulated wire
Aug. 1934	Copper prohibited for roofing, architectural parts and ornaments, moldings, posts, railings, etc. In general covers "Luxury" uses	
Dec. 1934 and Apr. 1935	Copper prohibited for long list of consumers' goods chiefly, including hardware, utensils, electrical appliances, etc. Also for certain automobile parts and accessories	Certain portions of electrical appliances such as current conduction parts
Apr. 1935	All manufacturers using copper of copper alloys cut to following percentages of consumption in 1934:	
	Item: Percent Copper.....40 Bronze and brass.....75 Other copper alloys...40	
June 1935	Quotas cut to 30 percent for copper and 20 to 50 percent for alloys	

June 1935 and Oct. 1935	Prohibition on use of copper and alloys for many uses in machine construction, including bearings, tubing for water, steam, air, and oil; fixtures; plumbing and heating equipment and other building uses; and certain electrical parts	
Aug. 1938	Copper prohibited in tubes of all kinds	
Mar. 1939	Quota system largely eliminated; superseded by specific allotments procedure	
June 1939	Additional prohibitions on use of copper in electrical equipment, including wire and cables	
Sep. 1939	Quotas, so far as still operative, cut to 15 percent for copper and 10 to 25 percent for alloys	Exemption of goods for export cancelled
Sep. 1939 to date	Many decrees issued consolidating, modifying, and extending prohibitions and restrictions already in effect. Undoubtedly net effect was to eliminate completely any remaining use of copper deemed not absolutely essential to the war effort. Also decrees for obtaining maximum amount of scrap and old metal	

SOURCE: Data compiled from official sources by Mr. Querin, European Unit, Bureau of Foreign and Domestic Commerce. Supplemented by items from German periodicals, chiefly Industrieblatt, der Vierjahresplan, and publications of the Institut fur Konjunkturforschung; also from German Metal and Mineral Notes, American Consul, Frankfort am Main.

APPENDIX B. SUBSTITUTION OF VARIOUS MATERIALS FOR COPPER IN GERMANY

	Use	Form in which copper previously used	Substitute material	German claims as to performance and saving of copper
1.	High-tension wire	Copper	Aluminum and steel-aluminum	Less weight of aluminum for same conductivity. Average annual installation of about 1,600 km. of high tension transmission cables, 1935-1938, of which 85 percent aluminum and steel-aluminum. In 1934, survey of whole German high-tension network, 24,950 km., showed 75 percent of copper and 25 percent of aluminum and steel-aluminum
2.	Insulated wire	Copper	Oxydized aluminum	
3.	Telephone and power switch parts, bus bars, guide-rails for electric railroad and trams, small wiring coils and other electrical parts	Copper and alloys	Aluminum, magnesium, laminated aluminum-copper (30 percent alum)	Good conductivity, reduced weight
4.	Tubes for air, water, fuels, chemicals, etc.	Copper, brass, and other alloys	"Hartporzellan"--porcelain	Unmatched for resistance to corrosion; also resistant to sudden temperature changes; considerable bending strength; rubber joints with screw couplings satisfactory

	Use	Form in which copper previously used	Substitute material	German claims as to performance and saving of copper
5.	Same	Same	Steel tubes fire-copper-plated or brass-plated	Saves one-third to one-half weight for same performance; saves over 90 percent former copper. Improved strength and resistance to vibration; also good resistance to corrosion
6.	Steam and water armatures, turbine blades, fixtures and fittings for equipment in beverage, dairy, sugar, and other food industries; soap, chemical, synthetic gasoline industries; ships, etc.	Copper, bronze, brass, and other alloys; nickel-steel; tin alloys; etc.	Chromium-steels (10-20 percent chromium); chromium-molybdenum steels; chromium-manganese-steels; also aluminum alloys	High resistance to acid, rust, sea-water, etc.
7.	Locomotive fireboxes	Copper	Steel	Reduce weight; excellent performance. Reported in January 1937 that German railroads, one of chief users of copper, had recently altered specifications for steam locomotives and thereby reduced copper requirements by about 7 tons per locomotive. Relates to fireboxes, bearings, etc.
8.	Fixtures, frames, etc., in buildings, ships, etc.	Copper, brass, and other alloys	Aluminum, magnesium, plastics, etc.	Increased strength; reduced weight; corrosion-proof, etc.

	Use	Form in which copper previously used	Substitute material	German claims as to performance and saving of copper
9.	Fittings, castings, etc.	Copper, bronze, and other alloys	"Giesche" and "Zamak" alloys, about 95 percent zinc with remainder aluminum, magnesium, or copper	Easily cast, rolled, or drawn
10.	Bearings for locomotives, vehicles, and machines of various sorts	Copper and bronze	Cast iron, aluminum, magnesium	Alloys with 95 percent aluminum show excellent results even under high pressures; have been used in thousands of German tractors for many years; growing use in locomotives
11.	Bearings and tooth gears	Same	Plastics	For certain uses plastic bearings 10 to 20 times as efficient as bronze
12.	Cables, coils, wiring harnesses, conduits, bearings, etc., for automobiles	Copper, bronze, and other alloys	Aluminum, copper-plated metals, lead-bronze	Use in radiators continues to be chief requirement for copper in automobiles. Germany uses considerably less copper per vehicle, perhaps 50 percent less, than in United States (with exception of German vehicles exported). Based on fragmentary statistics on copper consumption in German vehicles for 1936-39 compared with U.S. consumption
13.	Engraving plates	Copper and alloys	Magnesium and alloys	
14.	Small coins	Copper and alloys	Zinc and magnesium alloys	Much better than during World War

1. German Metal and Mineral Notes, American Consul, Frankfort-am-Main, November 9, 1935 (No. 239). World Electrical Markets--Germany--Part III--Power Distribution, S. E. Woods. Commercial Attache, Berlin. Special Report No. 68. November 9, 1939. pp. 10-12.

2. German Aluminum Developments, American Embassy, No. 1593, July 1, 1940, p. 5.

3. Ibid; also Der Vierjahresplan Sonderausgabe, Jan. 1939, pp. 65-66; Industrieblatt (Stuttgart), No. 1, Jan. 6, 1940, p. 25; ibid, No. 15, May 26, 1940, p. 544; also Progress in the Application of Light Metals in Germany, American Embassy, Berlin, No. 1979, Dec. 12, 1940.

4. German Metal and Mineral Notes, June 6, 1936; ibid, Feb. 27, 1937, No. 38.

5. Ibid, Jan. 19, 1938, No. 12; Industrieblatt, No. 1, Jan. 6, 1940, pp. 24-26, and No. 6, Feb. 26, 1940, pp. 199-200; Economic Journal, Dec. 1941, p. 418.

6. German Metal and Mineral Notes, June 17, 1936, No. 115; ibid, Aug. 13, 1940, No. 46.

7. Ibid, Jan. 30, 1937, No. 20, and March 31, 1939, No. 54; July 22, 1936, No. 136; Industrieblatt, No. 15, May 26, 1940, pp. 542 and 546.

8. Ibid; Industrieblatt, No. 15, May 26, 1940, p. 544.

9. German Metal and Mineral Notes, Dec. 12, 1936, No. 250, and Jan. 30, 1937.

10. Ibid; also Aug. 24, 1935, No. 187; Industrieblatt, No. 15, May 26, 1940, p. 546, and No. 17, June 16, 1940, p. 624.

11. Ibid, No. 15, May 26, 1940, p. 548; German Metal and Mineral Notes. June 24, 1940, No. 31.

12. Ibid, Feb. 18, 1939, No. 20; also German Economic Information from General Motors Officials, Confidential report of Interview with Directors of Opel Worke, Jan. 9, 1942 (Files of Economics Section, COI), p. 7.

13. Industrieblatt, No. 15, May 26, 1940, p. 544.

14. Ibid, p. 546.

APPENDIX C. INCREASE IN COPPER CONSUMPTION AND INDUSTRIAL ACTIVITY IN GERMANY AND GREAT BRITAIN: 1938 AS COMPARED WITH THE 1932-33 AVERAGE.

Item	Germany[1]	Great Britain
	Percent	Percent
Estimated actual cooper consumption (allowing for accumulation of a war reserve of 300,000 tons by September 1939).....	30	71
Total industrial production....	99	34
Machine building.....	230	64
Merchant shipbuilding.....	674	544
Motor vehicle production (trucks and autos only).....	355	64
Building materials and building.....	37[2]	9[3]
Chemical industries.....	131	16
Electrical goods.....	191	no data
Electric power consumption.....	114	77
Total mileage of telephone and telegraph wires.....	13[4]	38[4]
Total number of telephones.....	31[4]	47[4]

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[1] German figures apply only to the Old Reich.

[2] Building materials only. Increase from 1934.

[3] Increase from 1934.

[4] Increase from average of March 1933 and 1934 to March 1939.

Sources of data: League of Nations, Statistical Year-Book, 1939/40; Institut fur Konjunkturforschung (Berlin), Statistik des In- und Auslands, Jahrgang 1938/39; Metallgesellschaft (Frankfork), Metal Statistics 1929-1938; and American Telephone and Telegraph Co.